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GOVERNMENT CONSTRUCTION OF RESERVOIRS IN ARID REGIONS.

BY LIEUT.-COL. H. M. CHITTENDEN, U. S. A.

LIKE many other movements of profound and far-reaching possibilities, the project for government construction of reservoirs in the arid regions has passed its infancy amid the most adverse conditions. It has constantly been thrust aside as one of the innumerable schemes for exploiting the national treasury for the promotion of local industries. But its vitality has overcome all discouragements and has won for it a place of prominence among the living issues of the country. The latest national platforms of the two great political parties expressly indorsed the project, and even if these indorsements were mere "ornamental propositions," the fact of their adoption indicates the strength which the movement has acquired; and it is important that it be thoroughly understood in the East as well as in the West if it is to receive intelligent consideration from Congress. The object of this paper is to promote an appreciation of its importance by explaining what the reservoir question is, as understood in the arid section of the United States.

The industrial growth of any country and its capacity for a high civilization depend in an eminent degree upon its agricultural development. Manufacturing and commercial interests may fluctuate, mines may become exhausted, but the progress of the seasons perpetually renews the productivity of the soil, and only the indolence of man or the perversity of government can impair this elementary source of wealth and power. The state, therefore, regards its agricultural resources with a jealous eye, and so long as these are dwarfed and stunted from natural causes it feels that it cannot reach the highest goal of prosperity and enlightenment. Of the three million square miles, more or less, within the territorial limits of the United States, excluding Alaska and the Islands, about 1.3 millions, or 43 per cent., are not supplied by nature with sufficient rainfall during the summer season to sustain successful agriculture. In that section of the country, extreme conditions, as regards moisture, prevail. While the rainfall is deficient, the evaporation is excessive, and with each the extreme is experienced at a time when it works the greatest injury to cultivation. The result is that, throughout an area large enough to constitute a vast empire, veritable desert conditions prevail. Yet the soil over most of this area is good, over much of it excellent; and only water is lacking to make a large part of it as fine agricultural land as the world affords.

A remedy for this great drawback has been sought in irrigation, which means the artificial distribution of the waters of streams over the cultivable lands, so as to provide the necessary moisture for vegetation during the season of growth. In order to apply this remedy to any particular section of country, certain conditions are necessary. The land must be so situated, as regards its topography, that the distribution of water upon it is physically possible, and there must be a supply of water sufficient to irrigate it. No matter how much water there may be, nor how good the soil, if the land is so broken and precipitous as to make the construction of ditches impracticable, it is lost to agriculture. And on the other hand, no matter how extensive and well favored topographically a tract may be, if the water supply is deficient, a part of it, at least, must remain undeveloped. · A third condition should be added to these, viz., that the land must not lie above an altitude where agricultural products can be successfully grown, and this will generally exclude most lands of an elevation of over 7,000 feet.

A low altitude, an accessible topography and the necessary water supply are the essential natural conditions to successful irrigation. While none of these conditions can be reduced to such definite figures as to give, even with close approximation, the extent of area to which they apply, it is well established that the water supply will be the determining element. In other words, there is land enough at a favorable altitude, and well adapted to the construction of ditches, to absorb the entire available water supply. It is considered by some authorities that there is ten times as much irrigable land as there is water to irrigate it with.

The simple statement of this ratio, without reference to actual quantities, is sufficient to show how vitally essential to the agricultural development of this vast section are the conservation and judicious use of the water that flows in its streams. If we estimate the total annual supply of water, in that portion of the arid regions which is capable of irrigation, at 4,646 billions of cubic feet, or 107 millions of acre feet,* and assume that 1½ acre feet will irrigate an acre of ground for one season, the existing water supply is capable of sustaining agriculture on about seventy million acres. A possible maximum of one hundred million acres is claimed by some. On the basis of the density of population in the more highly cultivated sections of Europe, this area, under successful irrigation, will maintain as great a population as that of the entire United States in 1900.

It must not be supposed that the quantity of water stated above is available for irrigation by taking it directly from the streams in their natural condition. The regimen of flow in most streams is highly unfavorable to the economical use of their waters. Much of the water passes off in the seasons when agriculture is suspended. Other portions, the greater part, in fact, flow away in the period of the spring floods, and in such large volume as to be mostly wasted. In certain sections of the country, nearly all the rainfall occurs in the winter season and is lost; in others, the flow of the streams is spasmodic and irregular, produced by violent and sudden storms of short duration, and no dependence can be placed upon it. Nowhere does the water supply correspond to the demand for irrigation; but, generally, maximum supply meets minimum demand and minimum supply maximum demand with exasperating regularity.

Engineers variously estimate the proportion of stream flow that can be drawn directly from the streams and used in irrigation. It is determined by the amount which the stream affords when the supply, as compared with the demand, is the smallest. It is useless to take a large amount of water from a stream at a high stage and irrigate an extensive tract of land which cannot be supplied at a lower stage. The proportion of the flow that can be utilized directly varies widely with climate, locality and crops. In some places, it is as low as ten per cent.; in a few, higher than fifty. It is probable that, taking the country over, not more than twenty-five to thirty per cent. of the stream flow is capable of direct utilization, and the irrigable area dependent upon it is limited in like proportion.

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* This is equivalent to a depth of two inches over one million of square miles. The annual run-off from the Missouri watershed above Kansas City, based upon twelve years' observation, is 1.98 inches. The acre-foot is an amount of water which will cover an acre to the depth of one foot.

To utilize the two-thirds or three-fourths that go to waste, requires that a portion of it shall be stored and held until the occasion for its use arises. It is not necessary to store all in order that all may be used. If a certain amount is stored, to be used at the period of greatest deficiency, say in August, it becomes possible to draw considerably more directly from the stream in periods of excess, say in June, than could be drawn without this auxiliary supply for August. In general, it will be found that, for every cubic foot of water stored, nearly, if not quite, another cubic foot will be made available directly from the stream, so that storage will really count more than, possibly twice as much as, the amount actually stored.

Considering the fact that a portion of the flow of some streams can never be used at all, because they lie in such deep cañons or valleys that the water cannot be diverted upon the neighboring lands, it will be safe to assume that a storage equal to one-fourth of the entire run-off of the arid regions, as above computed, say 1,162 billions of cubic feet, will render available practically all of the water supply which can be used in irrigation. The value of this stored water, under a wise and conservative development of the system, will be very great. Considering that each acre-foot stored will make available probably two acre-feet, and that the value of water for irrigation, now ranging from fifty cents to three dollars per acre-foot per year, and in favored localities much higher, will certainly increase with time, it will not be extravagant to estimate the future annual value of this storage at two dollars per acre-foot, or $46,000 per billion of cubic feet. This would give the annual value of the total as $53,452,000, with the certainty of a constant increase.

Such, in briefest statement, is the reservoir problem of the arid section of the United States. It contains the possibility of a mighty empire in a region which nature has overspread with almost universal desolation. Is this problem one that can be successfully handled, and, if so, by what means?

As to the physical aspect of the problem, it may be a matter of doubt if reservoir sites, capable of an aggregate storage of eleven hundred billions of cubic feet of water, can be found where they will at the same time be available for an irrigation supply. These sites exist in all manner of places. The open valley sites are mostly among the mountains and require high and powerful dams. Lake sites, so called because they occupy natural lakes, are also generally well up on the courses of the streams. They constitute the most advantageous situations for reservoirs that nature affords. Then, far below the mountains, scattered among the foothills and well out upon the plains, there are natural depressions of varying magnitude which require only feeding canals and the necessary outlets to make them the most perfect and the safest of reservoirs. This last class of sites must be considered a wise provision of nature, for they are located ordinarily far enough down to gather in the supply which must always be lost to reservoirs among the mountains. Time will give to these natural basins a value in this connection which as yet is very imperfectly appreciated. On the whole, it is probable that the necessary sites can be found. Personal observation, covering a considerable portion of the central West, leads the writer to believe that a storage system can be constructed which, combined with a properly planned system of distributing works, will absorb most of the waters that now go to waste. Should this prove not to be the case, it will simply mean that the scope of the reservoir system and the cost of its construction will be less than here estimated. There is scarcely any probability that the future expansion of the system will exceed the estimate above given.

Concerning the cost of the work, it is clearly a difficult matter to give a precise estimate. It may be said, however, on the basis of existing works in the western country, that six dollars per acre-foot, or $138,000 per billion cubic feet, ought to cover the original cost of storage, if the work is done with reasonable system and economy. The cost of storing eleven hundred and sixty-two billion cubic feet of water will thus be in the neighborhood of $160,000,000. This seems like an enormous sum to put into reservoirs, or any other form of public work, and it is so, if considered as a matter of the present moment. But this estimate is for a completed reservoir system—a matter, not of to-day or to-morrow, but of the distant future. The storage of water will proceed *pari passu* with the extension of irrigation, and the storage system will be complete only when the irrigation system is complete. How long this will be, no one can foretell, but certainly not less than a hundred years. Thus the annual burden would be but one and a half to two millions of dollars, and the benefits from the work of the first few years would more than repay the cost of all that will follow.

A complete and comprehensive reservoir system throughout the arid section of the West being indispensable to the ultimate development of that section, and in all probability capable of realization, the question arises, by what agency can the work be best accomplished? As between the two broad divisions of public and private agencies, the question is not difficult to answer. Neither private individuals nor corporations can ever be relied upon to do this work as it should be done. In the first place, their resources will not ordinarily be sufficient. In the second, the immediate purpose for which a company or individual might build a reservoir will very rarely be such as to develop the full capacity of the site. When enough storage is secured to satisfy the purposes of the investment, nothing further will be done. Now, it is of the utmost importance, when the development of a reservoir site is commenced, that it be planned to secure the full capacity of the site, and that it be built in the most substantial manner. A defective work once located on an important site will be a perpetual bar to the construction of a suitable work.

Moreover, the government can profitably and properly undertake works of this character which would be ruinous to an individual. It is an erroneous idea that no public work is justifiable unless there can be collected from it a direct, tangible and profitable revenue, such as a private party would require. The public does not derive its return in the same manner as do private investors. In the case of a reservoir, for example, an individual or company will ordinarily build for a specific purpose, such as furnishing the water supply for a city, providing power to turn mills, storing water for the irrigation of land, and the like. Seldom, if ever, can all the uses to which stored water may be put be controlled by any company, and a portion of its benefits will always escape every effort to derive a revenue from them. But to the public, which builds these works from the revenues derived from general taxation, and looks for a return, not in the form of cash revenue, but in the general increase of wealth to the community resulting from these works, every use to which the water is put is a source of gain. The public is, therefore, in a position, as regards such works, which no individual or company can ever occupy, and the legitimate benefits accruing to it from identically the same work must necessarily be greater than can be realized by a private party.

Again, the government does not build alone for to-day or to-morrow, as an individual or company must do. No private investment can wait very long for an ample return. But with the government, whose life is presumed to be vastly longer than that of any company or individual, this is not the case. Far more important than immediate return is the character of the work constructed. It is better to build in the best possible way and wait a while for the return, than to build in a less thorough manner in order to derive an immediate return.

There are other considerations tending to the same general conclusion, that an adequate reservoir system in the arid regions cannot be realized except through the agency of government. Accepting this conclusion, the further question arises, through what form of governmental agency, state or federal, can this best be done? Without entering in detail into this subject, a few of its more salient features may be referred to.

Reservoir construction, as a public work, is essentially interstate in character. Very few of the streams of the arid regions, except on the Pacific coast, are confined to the limits of one State. As a rule, they pass through several States. The many streams that rise in Wyoming, for example, flow through or along the borders of some twenty other States and Territories. There are very few reservoirs of magnitude that could be built whose influence would not cross State lines and be felt in other States than those where the works are located. There are numerous sites near State boundaries where the waters from the reservoirs which might be built would flow immediately into the neighboring States and yield no benefit whatever to those in which they are located. In fact, the interstate character of these streams is certainly destined to raise questions in the near future which only federal authority can determine.

Again, if a comprehensive system of reservoirs is ever built in the West, its influence upon the floods and low water of some of our navigable streams will be a matter of public importance of which an individual State could take no cognizance.

In the matter of cost, the present resources of the States absolutely preclude most of them from undertaking works of this character. In some, the revenues are limited by their constitutions to a fixed percentage of the valuation, and there is no obvious way of creating a fund for such work.

It must not be forgotten, either, that the government is the principal land owner in the West. In some of the States nearly ninety per cent. of the land is still public. The storage of water by which more of this land may be reclaimed and settled is a simple business measure on the part of the government for enhancing the value of its own property.

There is an economic principle involved in this question which still more clearly indicates that the general government is the proper agency for the execution of these important works. Who shall own the waters of our streams, the general government, or individuals and corporations? The answer to this vital question must be forthcoming in the near future, not alone in those regions where the rainfall is deficient, but in those where it is abundant. The people of New York State have only recently extricated themselves from a dangerous situation, into which they had unwittingly fallen by giving away to a private corporation the control of the unused waters of the State. In the West, property in running water has long been recognized. By virtue of priority of appropriation, the waters of many of the streams have been converted into a commodity which the owners sell as they would cattle, grain or lumber. There is some color of reason in this where the appropriator has gone to expense in order to deliver the water to his neighbor; for he is then, in some degree at least, receiving pay for services rendered. Nevertheless, the system is inherently vicious, as is any system which gives to private agencies a monopoly of the resources of nature. The water of the streams should be the property of the public and should never be used for speculative purposes. Priority of appropriation should give the appropriator control of only so much water as he actually uses. If this is less than he is entitled to take from the stream, he should be required to let the surplus flow on where it can be beneficially used. Construction of reservoirs by private agencies is inseparable from speculative ownership of the water stored, and this cannot be effectually prevented unless the work is done by the government.

Closely related to this question is that of the future disposition of the public lands of the West. Very few appreciate what an opportunity exists, in the public ownership of so vast a portion of the national domain, for instituting a land policy which shall avoid the evils of the existing system. Monopoly of land is a monopoly of the opportunities of nature, and is being recognized more and more as one of the evils of our social system which remain to be corrected. The public domain of the West should be forever excluded from monopolistic control or speculative ownership, yet held open to secure occupation for all legitimate purposes of improvement or use. The land and the water should remain inviolate as the common heritage of the people.

It is now in order to examine some of the objections which are interposed against the policy of public patronage of these great works. It is urged by some that this would mean government control of irrigation works as such, with the dreaded ramifications and the unseen lengths to which such a policy might lead. If this were so, it would indeed be a powerful argument against the whole project. But there is no reason why government assistance in the one case should in any way obligate it to assist in the other. The reservoir is essentially a public work, interstate in character, its influence affecting a variety of objects. The irrigating ditch is essentially a local concern, not in the ordinary case crossing State lines. One work pertains exclusively to the stream, the other mainly to the lands. It is in every way better that distribution systems, water laws, etc., should be under the sole jurisdiction of the States, which occupy a position in regard to these works similar to that filled by the central government in other countries, as Canada, France and England. The States have demonstrated their entire capacity to handle these matters. A corps of trained engineers has grown up throughout the West, qualified in every sense to deal with all questions pertaining to irrigation. Certainly, it would be a great mistake to think of turning over works of this character to the general government at the present time, if ever.

But in the matter of storing water, as in that of preserving forests, the function is so clearly interstate in character, and the cost of the best kind of work is so great, that the general government is of necessity the proper agency to execute it. But let its function be limited to this object. Let it reinforce and extend the resources of nature and preserve them to the general use, but let that use be regulated by the same authority as at present.

It may be suggested that this is impracticable and that it will lead to clashing of authority. There is no reason why it should. Let the government, in improving a site, acquire full right, title and jurisdiction thereto. Let it build, own, maintain and operate the work itself, but let the stored water, after it leaves the reservoir, be absolutely free to the public, just as the works on rivers and harbors are free without toll or levy of any kind. The irrigator who wishes to take out a ditch from the streams below will go to the State Engineer and file his application just as he does now, and he will use his rights under the same regulations. The only difference will be that there will be more water available than there was before the reservoir was built.

Only two qualifications need be made to this statement: First, that the government should always reserve such control that it can at any time close the reservoir in case the prevention of floods* or other public emergency should require it; and, second, that the waters so stored shall be for the free use of the people and never be subject to speculative ownership.

A common argument against government construction of reservoirs in the arid regions is that it is in direct aid of private enterprise and, therefore, contrary to the spirit of our institutions. It is the policy of our government not to undertake works which can, consistently with the general welfare, be done by private agencies, nor to expend the public moneys in any work which benefits mainly or directly a private party only. So far as the works here considered fall within this definition, they would certainly not be justifiable under our system of government. We have endeavored to show, however, that a comprehensive scheme for the conservation of stream flow is in the strictest sense a public measure; that it relates to communities rather than to individuals; is interstate in character; affects in some degree navigable water courses; and cannot, consistently with the public welfare, be intrusted to private agencies.

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* To prevent any misconception as to the relation of reservoirs to flood protection, or any inference from this paper that the flood problem of great rivers, like the Mississippi, can be solved in this way, it may be well to state here that such flood prevention, as a motive for the construction of reservoirs, must always occupy a secondary place. From a superficial survey of the subject, it would indeed seem that in the building of reservoirs ought to be found the solution of many problems in river engineering which arise from a deficiency or excess of flow. Nature affords many examples of the effective moderating influence of reservoirs upon stream flow. The Great Lakes are an example, giving an almost uniform flow in the outlets where, in ordinary conditions, the high-water flow would be thirty times the low-water flow. Less striking examples abound over the surface of the globe. But when it comes to imitating these natural works by artificial ones, the obstacles are practically insurmountable. Very few sites of like magnitude exist, and if they did the land would be worth more in a cultivated state than the water which might be stored upon it would be in preventing floods. While, therefore, it is true that a reservoir is a perfect protection against floods for some distance in the immediate valley below, and while a great system of reservoirs might have some influence on the floods of the larger streams, as the Missouri, still these benefits will never be of sufficient importance, taken alone, to justify the construction of reservoirs. But when there exist other and more direct reasons, such as irrigation, which in themselves would warrant their construction, then the influence upon floods may very properly be given consideration as a secondary motive.

Finally, government construction of reservoirs in the arid regions is opposed by the Eastern farmer on the ground that under such a policy he would be taxed in the interest of competitors in his own line of business. Of all the plausible economic fallacies that find lodgement in the public mind, this has perhaps the feeblest foundation. It is like that other argument, which one hears nearly every day, that the invention of machinery restricts the field of labor. Although it has been proven, over and over again, that mechanical invention, by increasing wealth, has made possible the employment of labor on a scale that would be utterly impossible without it, still the advent of every new machine is condemned in many quarters as a new invasion of the rights of labor. So in the case here considered. The permanent establishment in the western country of a large and vigorous population would stimulate markets of all kinds in the East far more than it would depress any by reason of competition. Its agricultural products would be largely consumed at home, and it is absurd to talk of their entering the markets of the world in competition with products of the central West, where nature has lavished her favors in a fertile soil and generous climate beyond almost any other portion of the globe. If, perchance, certain products can be raised on these irrigated lands of better quality than elsewhere, is not the country as a whole the gainer by having them raised there? Does any one believe it would promote the general welfare to drive from the markets the fruits of Southern California, or the potatoes and melons of Colorado? It is one of the chief advantages of this great nation, where no custom houses restrict the free interchange of commodities between the States, that every community can enjoy what is best in every other community, and the whole country works together with a maximum of economy in promoting the public good. The agricultural interests of the East, and the narrow and provincial statesmanship which occasionally echoes their contention in this matter, should stand on higher ground. The upbuilding of the West will promote rather than injure their prosperity.

It remains to consider the duty of the government in regard to these works as a part of its policy of internal improvements. As public buildings, military posts, etc., are built exclusively for the transaction of public affairs, works upon rivers and harbors are the only important example of internal improvements which directly affect common business interests. These works began early in the history of the government and were justified on the ground that they were in aid of interstate commerce and, therefore, properly subject to federal control. Water transportation in those days was a matter of transcendent importance. Rivers were the great highways of internal commerce, and these were extended and connected by artificial waterways. It was an era of canal building and river improvement. The policy of federal aid in these works and the assumption of federal control of nearly all the navigable waters of the country became thoroughly established. Then came the railroad and with it a complete revolution in transportation methods. The old canals lost their importance and most of them were eventually abandoned. Commerce gradually left the rivers, and many a stream which was once the theatre of a prosperous traffic has not seen a commercial boat for years. The Great Lakes alone, of internal waterways, have maintained and increased their commercial importance.

But while this change has been going on, the policy of devoting public money to internal improvements has been kept up in increasing measure; and, strange to say, on the same old lines without any attempt to adapt it to changed conditions. In theory, these works are still carried on in the interests of navigation only. In practice, however, they have, to some extent, been forced into sensible conformity with actual business conditions. The protection of the bottom lands of the Mississippi against floods, and those of the Missouri against the ravages of that stream, has absorbed a large part of the appropriations for these streams in recent years. The utilization of the splendid natural facilities for storing water at the sources of the Mississippi, whereby a perpetual benefit has been conferred upon the country in upbuilding the industrial and manufacturing interests of that section, has likewise become a part of the scheme of internal improvements. These are public works of great importance, but the singular thing about them is that they are all carried out under the old theory of aid to navigation. This is not only a singular fact, but an astounding instance of the persistence of fictions in legislation long after the reality has ceased to exist. In reporting to the House of Representatives the Rivers and Harbors Bill at the last session of Congress, the committee having the bill in charge took occasion to animadvert severely upon the fact that a large portion of the appropriations for the Missouri River in recent years has gone to the protection of the property along the banks, instead of the improvement of the river for purposes of navigation. Yet the works of protection are of far greater public utility than those for improving the channel of the river. The navigation of the Missouri, wonderful as it was in its day, is dead beyond the slightest hope of resurrection. But during the process of its decay the fertile bottom lands have become farms and gardens among the richest in the world. The river in its reckless career plays havoc with these lands, and every year destroys property by the thousands. There is no power that can properly protect these lands but the general government, for the protective works invariably extend beyond the property lines of the individual, and often beyond the jurisdiction of the town, city or State in which the property lies. There is no duty of the government more deeply grounded in justice than that of protecting property holders from the ravages of this public watercourse. And yet, if any member of Congress were to ask for an appropriation for this specific purpose, his request would be summarily rejected, although, more likely than not, he will get the money if he pretends that it is for navigation.

Such a situation is discreditable to the intelligence of the country, and so long as it continues the Rivers and Harbors Bill ought to fail. If there is to be a system of internal improvements, it should stand on a business basis and keep in touch with the progress of the country. Where navigation has ceased, but other equally important demands for public expenditures have arisen in their place, these should receive consideration upon their merits. It is from this point of view that the people of the West regard the reservoir problem. They ask for nothing unreasonable. They support those measures which are building the great canals and harbors along the seacoast and the Great

Lakes, and they expect the country to support them in building equally important works which shall help make a garden of the desert and replace its languishing settlements with a prosperous population.

The first public work upon which the writer was ever engaged was the improvement of the upper Missouri River near the head of navigation at Fort Benton, Montana. The professional problems involved were interesting and practicable; but whatever satisfaction might justly attach to their successful solution was wholly neutralized by the reflection that the work was utterly useless. It is doubtful if from that day to this, eleven years, half a dozen commercial steamboats have passed over this section of the river. In an article which the writer prepared at the time, upon the history of navigation on the Missouri River, he made the following reference to this matter:

> "To see this great volume of water flowing down to the ocean while a rich prairie soil is parching in a rainless climate makes one wish that the government, instead of spending its money to contract and deepen the channel, would rather try to scatter its water upon the adjoining lands. By a strange misapplication of terms, streams are often said to *water* the valleys through which they flow, as if the exact opposite were not generally the case. But what greater boon could be conferred upon the Missouri valley than to make this misapplied expression a true one, even to the extent of draining the last drop from the river bed? * * * The question of thus utilizing the forces of nature may never, for many years certainly will not, receive serious attention. The river will flow on, undisturbed by the State, except that from year to year a few dams and dikes and shore protections will be built, a few gravel bars dredged away, and a few snags removed, all to make way for a commerce which, in sufficient magnitude to justify government appropriations, exists only in the imagination. But the dwellers of the valley being periodically pacified by these paltry pittances from the public purse, the paramount problem of making the river build up that country and convert those arid and barren wastes into productive farm lands will go on unsolved. Yet who can doubt that this is the true office of the mighty stream to the valley through which it flows?"

This opinion, somewhat exuberantly expressed, as to the proper objects for river expenditures in the Western States, the writer has yet seen no reason to change, unless it be to restrict the field of expenditure specifically to reservoirs, or to those great canals which may yet be built to distribute over vast areas the waters of the larger streams. H. M. CHITTENDEN.